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The Creation of a Global Telemedical Information Society

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Abstract

Healthcare is a major candidate for improvement in any vision of the kinds of "information highways" and "information societies" that are now being visualized. The medical information management market is one of the largest and fastest growing segments of the healthcare device industry. The expected revenue by the year 2000 is US$21 billion. Telemedicine currently accounts for only a small segment but is expanding rapidly. In the United States more than 60% of federal telemedicine projects were initiated in the last two years. The concept of telemedicine captures much of what is developing in terms of technology implementations, especially if it is combined with the growth of the Internet and World Wide Web (WWW). It is foreseen that the World Wide Web (WWW) will become the most important communication medium of any future information society. If the development of such a society is to be on a global scale it should not be allowed to develop in an ad hoc manner. The Euromed Project has identified 20 building blocks resulting in 39 steps requiring multi-disciplinary collaborations. Since, the organization of information is therefore critical especially when concerning healthcare the Euromed Project has also introduced a new (global) standard called "Virtual Medical Worlds" which provides the potential to organize existing medical information and provide the foundations for its integration into future forms of medical information systems. Virtual Medical Worlds, based on 3D reconstructed medical models, utilizes the WWW as a navigational medium to remotely access multimedia medical information systems. The visualisation and manipulation of hyper-graphical 3D "body/organ" templates and patient-specific 3D/4D/and VR models is an attempt to define an information infrastructure in an emerging WWW-based telemedical information society.

Introduction

Telemedicine is the interactive audiovisual communication between healthcare providers and their patients or other healthcare providers regardless of geographic distance. The first use of telemedicine dates back to 1969 when X-ray images were transmitted across telephone lines. Nowadays, the uses vary widely, for example:

1. Medical consultation during natural disasters.
2. The military has been using telemedicine in Croatia and Somalia to help treat wounded.
3. University hospitals are providing second opinions and continuing medical education to community hospitals.

The potential benefits for telemedicine are apparently well defined and justifiable. However, with the introduction of a new technology there are potential problems. Two abstracts taken from Medical Equipment International (February - March 1997) clearly illustrate the dilemma of adopting a new healthcare technology. Despite its numerous problems telemedicine is slowly becoming adopted as an alternative method of healthcare. During December 1996 U.S. and Israel physicians participated in an international Tele-collaboration by conducting a telemedicine exchange. An all day event on the campus of Israel's largest medical center (Rabin Medical Centre) located new Tel Aviv, with Texas children's Hospital and Baylor College of Medicine (Houston, TX, USA) and Duke University Medical Centre (Durham, NC, USA). The physicians participating in the exchange presented adult and pediatric cardiology cases for multisite medical collaboration including long distance transmission X-rays and ultrasound images. Also, in December 1996, during the Arab health exhibition held in Dubai, United Arab Emirates and two companies; VSI Enterprises (Noscross GA, USA) and interclinical Ltd (London UK) demonstrated live surgical procedures from Holland to physicians tin the Middle East. Live interactive demonstrations of coronary artery balloon angiography and coronary artery implantations were transmitted from Katherina Hospital in Eindhoven. Six cases were presented via video conferencing enabling the surgical team in Holland to demonstrate the clinical applications and techniques. There are many other numerous projects such as emergency telemedicine, Medical care in remote areas, home telemedicine and trans-national projects such as Telehealth Africa. The usage of telemedicine is becoming a global interest. For example in China, the Chinese Medical Information Network (CMINET) announced in March 1996 that CMINET will connect the Chinese Academy of Medical Sciences, Beijing Medical University, Peking Union Medical College and medical schools in Shangai, Zhejaing, Hunan, Xian, Huaxi, and Tibet. In June 1996 Guangzhoa Huamei Communications (GHC) involved a memo of understanding for very fast telecommunications and internet connections with the health division of the people's liberation Army (PLA) of China. GHC is affiliated with Chinese defense suppliers intends and plans to provide the PLA hospitals with ATM connections up to 155 Mbps. The PLA hospital intends to use the ATM connections to provide high-quality video telemedicine, combining education, radiology, sonography and nuclear medicine. So it can be seen that a global telemedical information society is a realistic possibility. The problem now is to develop a global standardized use of telemedicine to also incorporate the new advanced imaging techniques and sequentially the usage of supercomputing support. New advanced imaging techniques developed in the USA are behind new revelations about the mechanics of human thought. So promising are these techniques that the United States Congress declared the nineties the decade of the Brain. Researchers are on the verge of accurately charting different brain functions (the US project NEUROSCOPE - Real Time Acquisition, Control and Processing environment for Studies of brain functions using MRI, lead by University of Illinois). Modern neurology and neurosurgery make extensive use of medical images for both diagnostic and therapeutic purposes. Imaging modalities which are quite complementary may be used to display various anatomical structures. For example, X-ray Computed Tomography (CT) is relevant for a skull and ventricular system, Magnetic Resonance Imaging (MRI) is sui

to visualize cerebral tissues, Angiography (film-bakol or digital) is used to display blood vessels and Nuclear medicine (PET, SPECT) for functional imaging. Nevertheless there are potentially many situations where a clinician would like to inspect an area of intent using more than a single image system. Viewing different images side by side provide little detailed information of the similarities and the differences between them. Accurate alignment of such images provide anatomical and functional information in the set of superimposed data (such as the US project ANALYZE [5], lead by the Mayo Clinic which comprises of over 60 programs allowing fully interactive display, manipulation and measurement of multidimensional image data). Not restricted to computational neurology this technique can be used in application fields such as radiation oncology, plastic and re-constructive surgery, medical diagnosis and mammography forming the basis for developing computationally intensive virtual surgery and surgery planning techniques, such as VRASP being developed at the Mayo clinic [8,9].

One important consideration for the 21st century is to create a telemedical information society whereby patient's medical data can be accessed globally and transparently of any storage and communication medium. The medical data related to a particular patient may be in various mediums from textural reports to a surgery planning video. This information may also be located in various databases and hospital information systems. When all the patient information can be stored in a computer accessible medium and all the computers are connected in a global network, the most important element of such a society becomes the navigation of information. Additionally, when related to the medical discipline this navigation should be an abstraction from computerized jargon and communication pragmatics. The essence of a 21st Century medical information system, in an emerging telemedical information society is that multi-media systems will be accessible remotely via a homogeneous communication protocol. It is therefore envisaged that such navigation will be aided by realistic hyper graphical medical models, such models are shown in Figure 1.

Figure 1 Hypergraphical Medical Models

The elements of telemedical information society

Whatever form of an information society related to healthcare we can imagine, it will be based on three basic components, as shown in Figure 2, namely, raw medical data, reconstructed medical data and derived medical data.

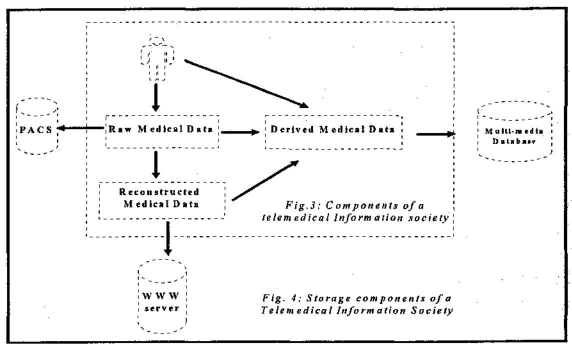

Figure 2 - Basic Components

The raw medical data will consist of the medical data that can be ascertained directly from the patient for example X-RAY, CT, MRI etc. There is now a defacto standard for this data called DICOM 3.0. The ACR-NEMA Digital Imaging and Communications in Medicine (DICOM) Standard has been developed to meet the needs of manufacturers and users of medical imaging equipment for interconnection of devices on standard networks. Its multiple parts provide a means of expansion and updating, and the design of the standard was aimed at allowing simplified development for all types of medical imaging. DICOM also provides a means by which users of imaging equipment may assess whether two devices claiming conformance will be able to exchange meaningful information. The future additions to DICOM include support for creation of files on removable media (such as optical disks or high-capacity magnetic tape); new data structures for x-ray angiography and extended hard copy print management. For further information the reader is referred to the Web page: http://www.xray.hmc.psu.edu/dicom/dicom_intro/DICOMIntro.html. The derived medical data will be the subsequent diagnosis and in various formats including text. The reconstructed medical data will consist of, for example, computer generated models. . The raw medical data will be stored in DICOM PACS and multi-media databases. The derived medical data will also be stored in multi-media RIS and HIS databases. The reconstructed medical data will reside on some computing device; we envisage this to be a WWW server. It is envisaged that that the communicating protocol will be the World Wide Web (WWW). The unique property of the WWW is that it provides a uniform meta operating system allowing computer platforms of various topologies to communicate. With the introduction of JAVA and JAVA Script it is now possible to run the same Application Programs (Applets) on various computing platforms without any porting problems. Schematically, this can be represented as Figure 3. Based on this methodology, the accessibility of patient information is reduced to the notion of navigating or surfing the Web space attributed to the medical domain.

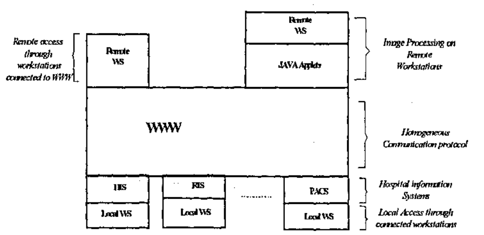

Figure 3 - Multi modal medical Information Systems

There are currently a number of software providers offering WWW Dicom Interfaces. One system is that implemented at the University of Joensuu within the framework of the Euromed Project. To use WWW-DICOM system, the user first runs a WWW browser such as Mosaic. Netscape, or Lynx and specifies a URL on one of DICOM PACS Unix workstations. This URL refers to an HTML file that contains a query form. This query form contains a number of fields such as patient name and medical record number. The user may specify any or all fields as well as wildcards in fields such as the name field. Once the form is completed, the user presses a button to submit the request. The HTML form submits the query to a CGI (Common Gateway Interface) program that executes on the DICOM PACS server. This program accepts as input the form field values that the user specified. This program then communicates with the archive via DICOM requests to determine those patients that match the search criteria. The user may then choose a patient, which in turn causes the studies for this patient to be displayed. Finally, the user may select a study which causes those images to be retrieved from the archive and displayed via the Web browser. The result of this system is an easy to use interface to a DICOM PACS with the option to query and move images from the PACS.

Alternative public DICOM implementations can be found at Pennsylvania State University, the University of Oldenburg and Mallinckrodt Institute of Radiology which is the premier of publicly available Dicom implementations. There are also a number of hospitals currently using WWW browsers to access a Dicom PACS system. One such implementation is at the Medical Imaging Unit Centre of Medical Informatics, Geneva University hospital where the conventional PACS environment was replaced by a prototype of the WWW browser that directly triggers a specific program for displaying medical images from the conventional Netscape or Mosaic browser. Especially designed interface written in HTML can be used from any conventional WWW browser or any platform.

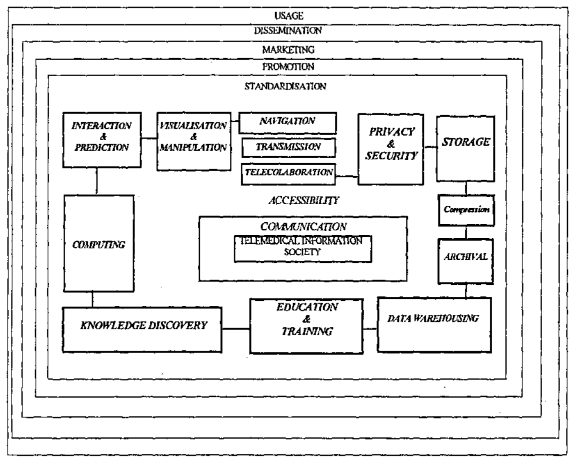

Figure 4 - Building blocks schematic

The development of a global telemedical information society should not be allowed to develop in an ad hoc manner. It is the objective of a European Commission funded project called Euromed [3, 5, 15, 16] to standardize the foundational elements of such a society. The project has identified 20 building blocks schematically represented in Figure 4. Consequently from the building blocks 39 steps have been defined. Each step is well defined and modular in nature. It is only when all the steps and therefore building blocks are put together that a telemedical information society becomes a realistic possibility.

The storage of data (medical information) is one of the most critical corner stones of the societies building blocks. For medical purposes this is becoming to be well defined in that all medical imaging data should be stored in Dicom 3.0 format in a picture archiving system referred to as PACS. If the World Wide Web is to be adopted as the **accessibility** medium and the Internet as the **communication** medium then there should be a WWW interface to the storage components. It is therefore envisaged that Hospital information systems, PACS and any other storage mediums shall be Web accessible. The integration protocols between PACS/HIS and other information systems such as Radiology information systems should be based on well defined HL7, Dicom 3.0 and Web protocols such as HTTP. Consequently, further HIS implementations should be based on Web interfaced multi-media systems, whereby all the data should be viewable by a Web browser. Alternative databases such as video archiving systems should also be designed with Web interfaces.

Clearly, by making the medical information systems accessible by the Web raises problems of unlawful access. Therefore, another building block in the society should control the **Privacy and Security** of the stored data. A European funded project called Euromed-ETS is dealing with the issues of security of WWW-based telemedicine. The recommendations of this project is to adopt Trusted Third Party services for the management of unique keys, such as the client certificate server developed by Netscape and the usage of shttp for the communication protocol. Clearly, a lot of work needs to be undertaken regarding privacy and the issues of data protection, reliability and integrity. However, many of these issues can be borrowed from the commercial commerce society.

Assuming that the medical data can be stored and accessed in a confidential manner, the next important building block becomes **navigation.** To reduce the burden of surfing the Web for related patient information, EUROMED has defined the concept of **Virtual Medical Worlds**. Virtual Medical Worlds is built upon the components; medical images (in Dicom 3.0 format) stored in PACS, reconstructed medical pictures (in VRML 2.0 format) stored on WWW servers and medical application packages (that can utilize the X windows protocol). It is also assumed that every medical institution in a telemedical information society will have a computer on the Internet (i.e. have an IP address) running as a WWW server. Additionally, major health centers will have PACS and medical application packages.

The concept of healthcards is now being defined so it is not unrealistic to image that every member of the community will have a unique Virtual Medical World Personal home Page (PHP). The PHP will be located on a unique WWW "Virtual Medical Worlds" server. From the PHP a practitioner can trace all the medical history related to the patient. The PHP is an html page that will be divided into four sections. The first section will point to general administrative information related to the patient for example account status e.t.c. The second section will contain general personal details such as a hyperlink to the patient's address, historical details such as a hyperlink to the diagnosis reports and a hyperlink to the Virtual Medical Worlds environment related to the patient. The Virtual Medical Worlds environment is hypergraphical and is broken down into whole body templates. Atlas templates, organ templates, patient specific models and medical images/reports. The latter may be any information related to the patient that can be accessed by any Web browser. The former templates and patient specific models are in VRML format. Typically, The VMW link from the PHP will point to a VRML world containing whole body templates. At this level the whole body is represented in 3D VRML and annotations can be added to hyperlink to a more detailed model such as the torso. The notation of hypergraphical templates is consistent from all parts of the body. To access an image from a PACS server using the WWW interface. The pragmatics of the accessibility and location of the medical need to be known by the practitioner.

The navigation of a patient's healthcare record now consists of following hyperlinks around the Web space attributed to the telemedical information society. To avoid following unnecessary links shortcuts have been added in the PHP link to the respective levels of templates and patient specific information. A practitioner from the PHP could then trigger the request to accept a specific medical image instead of following the hypergraphical route.

Identifying the locality of medical information is the first step towards its usage. The **transmission** of this data over the network becomes critical when considering the bandwidths of today's networks. The issues of transmission of medical data and compression are closely linked. For the purposes of the paper the topic of compression relates to the storage of the medical data and minimizing the required space. Whereas transmission relates to minimizing the time the practitioner has to wait in order to view the medical data. Of course if the data to be transmitted is compressed, the amount of data to be transmitted is therefore reduced and hence less time is taken in the transmission. However, since the compression of medical data is a complex issue at present an alternative method maybe to transmit medical images in a progressive manner or even in a selective manner. For example, general information maybe transmitted at first and then progressively more detail. If the practitioner wishes to wait the complete time all the data as presented in the original format will be acquired. However, at any instance the practitioner may have enough information to make diagnosis. Additionally, the practitioner could indicate at the general level a specific area of interest what could be transmitted first and then the remaining data progressively. The topic of progressive transmission is an ongoing area of research but it is hoped that it will be enclosed in the definition of Virtual Medical Worlds for both 2D and 3D medical images.

The real benefit of telemedicine is that more that one practitioner can **telecollaborate** (e.g. view the same medical data simultaneously). With Web based tools this becomes easy by the using plug-ins such as Cooltalk. Cooltalk has a shared whiteboard, talk facilities and can even be combined with video conferencing facilities. The shared whiteboard can be used to view and annotate the same image simultaneously on two Web connected workstations therefore facilitating the tele-aspect of telemedicine. Clearly, furthermore sophisticated plug-ins and video conferencing tools can be used but Cooltalk provides the first easy solution.

For **Visualisation** purposes a VRML browser can be used to view Virtual Medical Worlds and reconstructed images from-raw medical data. For example CT slices to VRML, could be done on the fly by a JAVA applet. JAVA could also be used to **manipulate** the VRML models, performing tasks such as intersection and measurement analysis. Due to its characteristics JAVA is platform independent therefore the developed applets could run on any Web browser.

The ultimate objective for imaging is the **interaction** and **prediction** with the medical models. The interaction is in the form of surgery planning and surgery assistance, making use of Virtual Reality techniques, such as VRASP developed at Mayo clinic. The prediction aspect includes medical physics for determining blood flow analysis and tumor growth. Clearly, both interaction and prediction require a vast amount of **computing**. This should be provided either by a connection from a hospital to a computing site or by using the hospital computers in a collaborative network.

Returning to the corner stone of storage, a general hospital over a one year period will require on average 6,000,000 MB of disc storage. From this storage requirement only 10% of the data will be requested after the initial two weeks of data acquisition. It is envisaged that archiving sites will be set up so that a hospital can download the requirements of vast amount of storage to an external site. In conjunction with **Archival** is the compression of the data. **Compression** is a current topic with a large amount of interest due to its legal implications. However, techniques such as wavelet compression could provide the answer.

In a telemedical information society the collection of vast amounts of medical data will not only support the requirements of archiving but also provide a platform for the application of data mining and **knowledge discovery** to determine possible medical trends and the real data to support **educational training**. New technology in the form of **data warehousing** provides the potential to store the required amounts of medical data. It is envisaged however that a hierarchical approach will be adopted for the storage of data. This also has implications for the networking infrastructure. The hierarchical infrastructure will consist of hospital PACS, regional PACS, National PACS and a European PACS. Each PACS system outside of the hospital PACS can be regarded as a data warehouse and consists only of the archiving component of a complete hospital PACS environment.

It is envisaged that the medical imaging data related to a particular patient will reside on the hospital PACS up to an expiring date, before the end of this expiring date the medical imaging data will be copied to the Regional PACS. The medical imaging data will then reside on the Regional PACS up to an expiring date. Again before the end of the expiring date it will be copied to the National PACS, and so on. After a period of maybe up to a year the data will finally reside on the National PACS with a copy on the European PACS. At any moment in time after the initial period the patient medical imaging data will reside on two PACS systems therefore facilitating the concept of reliability the data.

In order that the core building blocks cooperate in a collaborative manner their interfaces and individual components must be **standardized**. It will be the role of standardized bodies such as CEN TC 251 to coordinate such interactions. The remaining four building blocks relate to how this new society will be used. The society must be **promoted** through various **marketing** channels so that medical vendors take an integral part in the development of the society. Then via varying initiatives the implications on the health care community should be presented so the results can be **disseminated** to the **end users.**

Summary

A global telemedical information society has been envisaged that can be built upon 20 building blocks. Each building block is well defined and its interaction well understood. The society should be built upon the existing well defined medical standards such as Dicom 3.0 and HL7 and the computing networking standards of the World Wide Web such as VRML, html, http etc. By building the society with this modular approach allows for the independent development of independent elements. The consequence of defining the 20 building blocks is the following 39 steps:

1. Static Communication using Internet.
2. Dynamic Internet Communications for emergencies.
3. WWW as Access protocol.
4. Store medical images in Dicom PACS.
5. Store non-medical images on WWW Server.
6. Use Trusted - Third party services for security.
7. Support Patient - doctor privacy.
8. Use hypertext to navigate documents.
9. Use hypergraphics to navigate models.
10. Transmit images progressively.
11. Communicate by Netscape mail.
12. Discuss with Netscape news.
13. Collaborate with Cooltalk.
14. Use VRML browser for visualisation.
15. Use JAVA for model creation.
16. Use Java for model manipulation.
17. Support mathematical modeling.
18. Batch-processing surgery planning.
19. High speed links surgery assistance.
20. Cgi-bin common interface for meta computing.
21. Multi-platform meta computing.
22. Workstation clusters for computing resources.
23. Wavelets for archival compression.
24. Intelligent medical image compression.
25. Hierarchical archival procedure.
26. Collection of medical information in Data Warehouses.
27. On-line Web-based anatomy atlas.
28. On-line Web-based medical databases.
29. Knowledge discovery identify pathologies.
30. Data mining identity statistics.
31. Standardized data interfaces.
32. Standardized user interfaces.
33. Hard copy promotion of Web-based telemedicine.
34. On-line promotion of telemedicine.
35. Integrated Web-based telemedical products.
36. On-line magazine.
37. Use of patient data locally.
38. Use of patient data remotely.
39. Use of patient data instantly.

For the envisaged healthcare society of the future to be a realistic possibility, a global co-operation needs to be established combining on a World Wide scale academia, industry and government. *The 20 building blocks have led us to the 39 steps to be able to create the healthcare community of the 21st century.*

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